Federal Communications Commission
Spectrum Policy Task Force

Report of the Interference Protection Working Group

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Interference Protection
Working Group

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I. Introduction

The Interference Protection Working Group ("Working Group") of the Commission's Spectrum Policy Task Force **is** pleased to present its findings and recommendations.[1] The Working Group was established to assist the Task Force identify and address spectrum policy issues and challenges involving interference protection. To that end, it reviewed comments filed by parties responding *to* the Task Force's Public Notice of June ***6,*** 2002, particularly comments relating to interference protection (ET-Docket No. 02-135). On August 2, **2002,** it participated in a public workshop on Interference Protection ("Interference Protection Workshop") that addressed "Interference Challenges, Advanced Technology and **A** Better Process."[2] This report summarizes the Working Group's analyses and presents its findings and recommendations. Some recommendations are intended to enhance interference management in the near-term, while others address longer-term challenges.

Interference protection is central to effective spectrum management. Electromagnetic interference plays a pivotal role in the design and operation of telecommunications equipment and systems, and related costs. In today's radio frequency environment, interference generally limits the useable range or technical effectiveness of communications signals. Its effects on spectrum users and service providers range from annoyance, to economic harm, to threats to the safety of life and property. Interference protection is fundamentally related to spectrum rights and obligations. It also affects the efficiency ***of*** spectrum use. Regulatory interference protection standards that are too lax could prove detrimental to existing or planned services. Conversely, standards that are overly protective could prevent or impede the introduction of new services and technologies.

Interference protection has always been a core responsibility of the Commission. Section 303(f) of the Communications Act of 1934 as Amended directs the Commission to make regulations it deems necessary to prevent interference between stations, as the public interest shall require.[3] The Commission's strategic plan for the years 2003-2008 includes as a spectrum-related objective the "vigorous protection against harmful interference..."[4]

Interference protection is addressed in virtually all of the Commission-regulated services that use the radio spectrum. Historically, various approaches have evolved for managing interference. Typically, FCC rules and policies have been tailored to the expected uses and technical characteristics of particular services at the time of their creation. Most services have common elements aimed at interference protection such as limits on in-band power and out-of-band emissions, For many wireless and satellite services, the potential for interference **is** evaluated by outside frequency coordinators.

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[1] The Interference Protection Working **Group is** an interdisciplinary group of staff from across **the** Commission's Bureaus and Offices.
[2] **A** transcript of the public **workshop** is available at the Task Force's web site, http://www.fcc.gov/spft.
[3] 47 U.S.C. § 303(f).
[4] *See Federal Communications Commission Strategic Plan FY 2003 – FY 2008*, available at http://www.fcc.gov/omd/strategicplan2003-2008.pfd.

Negotiated interference agreements among affected parties are also permitted in numerous services.

The record in this proceeding indicates that many of the Commission's rules and processes for managing interference have been generally successful. In recent years, few instances of systemic interference have been directly linked to Commission allocation or licensing processes? Industry sources suggest that formal and informal frequency coordination processes have been effective.[6] The Commission has implemented new services by means of a variety of ***ad** hoc* approaches. Existing services have been able to grow and add new features resulting from the flexibility for licensees to make technical and operational changes.

II. Future Challenges Warranting Consideration **of** New Interference Protection Paradigms

As reflected by commenters and workshop participants, there are rising concerns that future spectrum demands will challenge current interference management paradigms. First, many radio communications services have grown substantially in recent years. For instance, Stratex Networks, Inc. comments that the 6, 11, 18 & ***23*** **GHz** bands in the Common Carrier and Operational Fixed Services in New York City, Los Angeles, Chicago, San Francisco, Philadelphia, Boston and Washngton, D.C. have exhibited growth rates ranging from 15 percent to 900 percent.' The median growth rate for these cities and bands is 150%. Sprint comments that in the six years since they and other PCS licensees entered the market, "The number of mobile customers has nearly quadrupled, from **33.8** million in December 1995 to **128.4** million in December 2001.[8] According to Sprint, **58** percent of all Americans 12 and older now subscribe to a mobile service.

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[5] An example is the on-going conflict in the 800 MHz band, involving high power commercial radio transmitters and vulnerable mobile public safety receivers operating in close proximity on adjacent frequencies. The potential for interference between these services worsened **as** commercial licensees evolved the nature of their operations from SMR service (with relatively few stations serving wide areas) to a cellular service (with many stations serving smaller areas). The rules for interference that were established to manage interference in this band were developed years ago and currently do not appear to be sufficient. This conflict underscores the tension that can arise between flexible service offerings and the certainty of interference protection. ***See*** In the Matter of Improving Public Safety Communications in the 800 MHz Band and Consolidating the 900 MHz Industrial/Land Transportation and Business Pool Channels, *Notice of Proposed Rule Making* in WT Docket 02-55, 17 FCC Rcd 4873 (2001) (800 MHz Proceeding).

[6] For example, while acknowledging the interference conflict at 800 MHz, Glen Nash, past President of the APCO, Int., stated at the August **2,2002,** Interference Protection Workshop: "We really don't have a problem, Where we've gotten into trouble is when **people** don't want to play the game." Dr. Andrew Clegg of Cingular Wireless LLC added that interference provisions for the PCS service (powerlimit, boundary field strength limit and informal licensee coordination) work well and, in his opinion, could serve as a model for the future. Other participants at that workshop indicated that many interference problems are solved through cooperation among the parties through facilities adjustments. According to David Hageman of Poka Lambro Telcom, interference **is** not a major issue in **rural** areas.

[7] Comments of Ronald D. Coles on behalf **of** Stratex Networks, Inc. at ***5.*** According to Stratex, anecdaal evidence indicates "that in major metropolitan areas it **is** becoming more difficult to coordinate frequency pairs in the preferred bands of 11 & 18 GHz."

[8] Comments of Sprint Corporation at **2.**

A second challenge is presented by the explosive consumer demand for RF devices. The comments of the Consumer Electronics Association ("CEA") illustrate the large variety of very low power small-range RF devices in common use, including garage and car door openers, baby monitors, family radios, wireless headphones, and wireless Internet access devices using Wi-Fi™ or Bluetooth™ technologies.' According to CEA, the most common wireless device is the cordless phone, with 2001 sales of almost ***36*** million units.[10] By the end of the year more than 10 million computers are expected to use wireless networking technology and the wireless LAN industry is expected to reach a value of $5.2 billion by 2005.[11] CEA forecasts that, "As people become more mobile, moving from the office to the home, *to* the coffee shop, or to the airport, wireless networking application will become increasingly pervasive."[12]

The cumulative impact of the increasing volume and density of radio devices on the RF environment will challenge the Commission's current approaches to interference management." Dr. Paul Steffes of Georgia Tech University, who is the past Chair of the Committee on Radio Frequencies, represented the interests of radio astronomy at the FCC's Interference Protection Workshop. He indicated that the radio astronomy community, which pays attention to the growth of spectrum use, has observed an explosion in spectrum **use** around the passive services. According to Dr. Steffes, "Just because we know the rate of growth is so significant, the minimal pressures now will become major pressures within the next four years."[14]

The National Aeronautics and Space Administration ("NASA") also comments on the burdens placed on the ability to manage the spectrum, due in pan to the "tremendous" growth in personal communications devices and the increased congestion over the past ten years or so.[15] According to NASA, "All the best allocation and assignment processes which maximize the use of the RF spectrum are to no avail if the RF environment becomes corrupted and interference becomes 'harmful' to radio services depending on that spectrum for fulfillment of mission goals."[16]

Cingular Wireless LLC reports on some of the activities and findings of the FCC's Technological Advisory Council ("TAC")[17] that relate *to* the state of the RF noise environment.[18] Among the TAC findings cited by Cingular are the following:''

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[9] Comments of CEA at 2-4

[10] ***Id,***

[11] ***Id.***

[12] *Id.*

[13] At the Interference Protection Workshop, Dr. Clegg made **the** following statement about interference: "I think I can predict the future fairly confidently **that** we're going to see the same that we see today, but we're going to see **a** lot more of it.. .and it's going to be a gradual thing. It may not be so obvious on a day to day basis, hut the interference will increase.''

[14] Interference Protection Workshop remarks of Dr. Paul Steffes.

[15] Comments of NASA at 6.

[16] ***Id.***

[17] The TAC **was** created for the purpose **of** advisingthe Commission on the impact **of** emerging technologies and other spectrum management issues.

[18] Comments of Cingular Wireless LLC at 37-38.

> [There] "could be a very serious emerging problem caused by the explosive growth of both intentional and unintentional radio sources. The future could be very different from what we might expect from past experience. The key to getting our hands around this issue will be a good set of models for both intentional and unintentional radiators which can then be used to predict the evolution of the noise background." ***Second Meeting Report of the TAC at 1, 9.***

> "[W]e could potentially be entering a period of rapid degradation of the noise environment. Such degradation would reduce our ability to meet the communications needs of the country. The principal negative impacts are likely to be reductions in the performance or reliability of wireless systems or increases in their costs." ***Fourth Meeting Report of the TAC at 23 (Annex 4).***

Cingular Wireless comments that the Commission accepted TAC recommendation to undertake a multipart study of the noise floor. Two of the seven findings of the first step of this study are given below: [20]

> "Until [noise floor] information is organized and analyzed, the FCC will not have a firm basis for deciding whether current noise standards are too tight, too loose, or maybe even just right." ***Sixth Meeting Report of the TAC at 9.***

> "As we enter the new millennium, new noise sources are being developed (e.g., ultrawideband devices), and other electronic devices continue to proliferate as fast as the technology and the regulatory process will allow. Many of these other individual sources of "noise" may meet the current Federal Communications Commission (FCC) rules, but in great numbers they may negatively affect the overall electromagnetic noise environment. ***Sixth Meeting Report of the TAC at 25.***

A third interference management challenge is presented by the migration from a relatively small number of waveforms to widely varying signal architectures and modulation types for voice, video, data and interactive services. Even single classes of users are now using a wide variety of digital technologies. Cingular Wireless notes that CMRS licensees "commonly use analog AMPS technology and four different digital technologies (TDMA, CDMA, GSM and iDEN)" and that other more advanced technologies will follow.[21]

Under the current interference management approaches, tension is likely to arise between the competing Commission objectives of flexible service offering and well-defined protection rights.[22] If flexible use is to be fully realized, it will become

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[19] *Id.*
[20] *Id.*
[21] *Id.* at 12.
[22] The potential for mutual interference among different waveforms sharing the same or adjacent spectrum has not been fully quantified. It is easier to design rules to protect transmissions with the same known waveforms than to protect a waveform of one type from many (possibly variable) waveforms.

increasingly difficult to predetermine interference ranges. Worst-case propagation analysis may not always be applicable. Laboratory testing to demonstrate the spectrum sharing compatibility of two or more waveforms will become increasing complicated, time consuming and costly.[23] In Dr. Steffe's view:

> "The problem, of course, for the future is complexity. Obviously, the number **of** users and the management of the problem becomes dramatically enhanced...we were saying that it's [consideration of interference] at least a six dimensional problem, meaning spatial, x-y-z, frequency, time and waveform, and of course since the wave form can be infinitely complicated, you can make it an n-fold problem, which basically has more variables than you have numbers."[24]

Due to the complexity of interference issues and the RF environment, interference protection solutions may largely be technology driven. As a fourth challenge, the Commission will need to keep abreast of the rapidly advancing technology, in order to promote and empower its use. Due to advances in digital signal processing and antenna technology, communications systems and devices are becoming more tolerant of interference through their ability to sense and adapt to the RF environment. According to Dr. Raymond Pickhotz of George Washington University, it is important to recognize the impact of different kinds of interference, "not all of which are bad," on **a** particular technology.[25] Sources of signal impairment in wireless systems include internal (or self-generated interference), external interference and various sources of noise. Dr. Pickholtz indicated that in some systems of cooperative users (e.g., systems that use Code Division Multiple Access technology), "you can actually exploit the fact that there's a lot of a *priori* knowledge about the nature of the interference and either eliminate it or minimize it the point where it's not very important...[T]he concept here **is** that to the extent that you can avoid interference and not treat it as it if was noise you can increase the [system] capacity and therefore get more revenue...CDMA handsets use intersymbol interference to improve performance."[26] Dr. Pickholtz added that other types of interference, for example from external sources, may be similar to thermal noise, which cannot he mitigated by digital signal processing.

Thus, the Commission will be challenged to understand the rapidly changing communications technologies and the interactions of diverse signals. The Commisson will also need to keep abreast of advances in spectrum monitoring and measurement technologies.

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[23] The compatibility of new technologies wih those used by incumbents is often demonstrated by subjective and objective laboratory and/or field-testing. Separate tests are conducted to determine the impact of a new waveform on each existing waveform that will share the same or adjacent spectrum. **As** the number of available signal waveforms (and combinations thereof) continues to **rise,** the compatibility testing process will become increasingly unwieldy and, unless the process is streamlined in some fashion, it could jeopardize the ability of technologists to bring their products to market with their economic window of opportunity.

[24] Interference Protection Workshop remarks of Dr. Paul Steffes.

[25] Interference Protection Workshop remarks of Raymond Pickholtz.

[26] *Id.*

III. Nature of Recommendations

The Interference Protection Working Group recommends consideration of the following paradigms to supplement current interference management approaches, which the Working Group believes will significantly help the Commission meet its future challenges: Quantification of Acceptable Interference Levels, Transmitter Enhancement for Interference Control, Allocating Spectrum to Radiocommunications Services that are Grouped Together by Their Similar Technical Characteristics, Inclusion of Receiver Standards/Guidelines (through incentives, mandates, or a combination of these), and Improved Communications on Interference Issues with he Public. The Working Group submits it analyses, conclusions and recommendations for each of these.

IV. Quantification **of** Acceptable Interference Levels

A. Current regulations **and** statutes

Two key questions raised in the June 6,2002, Public Notice are whether the Commission's current definitions of interference need to be changed and whether more explicit protection from harmful interference should be provided to incumbent spectrum users." The Commission's Rules define four levels of interference:

> ***Interference.*** The effect of unwanted energy due to one or a combination of emissions, radiations, or inductions upon reception in a radiocommunication system, manifested hy any performance degradation, misinterpretation, or **loss** of information which could he extracted in the absence of such unwanted energy?
>
> ***Harmful Interference.*** Interference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with these [International] Radio Regulations.[29]
>
> ***Permissible Interference.*** Observed or predicted ***interference*** which complies with quantitative interference and sharing criteria contained in these [International (FCC)] Regulations or in ITU-R Recommendations or in special agreements as provided for in these Regulations.[30]
>
> ***Accepted Interference.*** Interference at a higher level than defined **as** permissible interference and which has been agreed upon between two or more administrations without prejudice to other administrations."

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[27] *See* Public Notice, "Spectrum Policy **Task** Farce **Seeks** Public Comment on **Issues** Related to Commission's **Spectrum** Policies." Questions *I* and 9, **DA** 02-1311 (**June** 6.2002).
[28] 47 C.F.R. § 2.1(c); ITURR 1.166
[29] 47 C.F.R. § 2.1(c); ITU RR 1.169.
[30] **47** C.F.R. § 2.1(c); ITURR 1.167.
[31] 47 C.F.R. § 2.1(c); ITU RR 1.168.

These definitions of interference, which are decades old, are also found in the international radio regulations. The terms *permissible* interference and accepted interference are used in the ntemational coordination of frequency assignments between administrations.[32] The Commission's service rules for a number of radio services include the definition of harmful interference given in § 2.1(c).[33]

The terms interference and harmful interference also are found in the Communications Act of 1934 *as* Amended

- **Sec. 302 [47** U.S.C. **302(a)]** Devices which interfere with radio reception. "(a) The Commission may, consistent with the public interest, convenience, and necessity, make reasonable regulations, (1) governing the interference potential of devices which in their operation are capable of emitting radio frequency energy by radiation, conduction, **or** other means in sufficient degree to cause harmful interference to radio communications; and *(2)*..." (emphasis supplied).

- **Sec.** 303 **[47 U.S.C. 303**] General powers of the Commission. "Except as otherwise provided in this Act, the Commission from time to time, as public convenience, interest or necessity requires shall —

* * * * *

(f) Make such regulations not inconsistent with law as it may deem necessary to prevent interference between stations and to carry out provisions ***of*** the Act: Provided, however,... (emphasis supplied).

* * * * *

(y) Have authority to allocate electromagnetic spectrum ***so*** as to provide flexibility of use, if –

(1) such use is consistent with international agreements to which the United States is a party;

and

(2) the Commission finds, after notice and an opportunity for public comment, that –

(A) such an allocation would be in the public interest;

(B) such use would not deter investment in communications services, **or** technology development; and

(C) such use would not result in harmful interference among users." (emphasis supplied).

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[32] ***Sue*** Comments of the Satellite Industry Association **at** 10, which **note** that the term "acceptable interference" can be used in the coordination process to define limits to protect against unacceptable interference.

[33] *See*, **for** example, **47** C.F.R. §§ 21.2, 90.7 and 101.3, which give the definition for *harmful* ***interference*** for the Domestic Public Fixed Service (Multipoint Distribution Service), Private Land Mobile, and Fixed Microwave Services, respectively. Means of applying this definition vary with **the** nature **of** the service; for example, the definition is applied differently depending on whether **a** particular spectrum band is available **for** exclusive or shared use. Note also that ***47*** C.F.R. § 15.5(b) conditions the operation of unlicensed intentional and unintentional radiators on not causing harmful *interference* to an authorized radio station.

The means of interference protection vary for different radio services. The most common elements are limits on transmitted in-band power and out-of-band emissions. Outside frequency coordination **is** employed in many wireless telecommunication and satellite servics and in the broadcast auxiliary services. Negotiated interference agreements are permitted in many services.

The service rules vary considerably regarding how interference is quantified, predicted or otherwise managed. Several examples illustrate the different approaches. Licensees in the PCS and some Private Land Mobile Services must limit their signal strength to prescribed values along their geographic boundaries to protect licensees in adjacent areas. Some land mobile services use minimum stationseparations corresponding to different power and antenna height combinations. The extent of interference protection afforded to analog television broadcast stations is defined by minimum station separations between stations assumed to be operating with the maximum allowable combination of antenna height and power. Power flux density limits are commonly used as a means of protection in many Satellite services.

The rules for some services prescribe detailed criteria for predicting interference at protected service locations. For example, the service populations of digital television stations are protected on the basis of calculations of desired–to-undesired signal strength ratios at locations where service is predicted to occur in the absence of interfereme. The Multipoint Distribution Service rules prescribe a rigorous interference methodology for two-way communications systems, based in part on an assumed statistical distribution of the subscriber locations. The frequency coordination process for some point-to-point microwave operations considers harmful interference to occur if a transmitter would "degrade the threshold of a victim receiver by no more than 1 dB."[34]

B. Views expressed in the public record

<u>Definitions of "interference" and "harmful interference"</u>: Commenters are divided on the need for new definitions of ***interference* and *harmful interference.*** Some favor retaining the current definitions. The comments of Nortel Networks reflect several of the reasons given by commenters supporting this position:

> [the] "current definitions are generic, and allow appropriate interpretation on a case-by-case basis ...More rigid definitions may inhibit the industry and stifle innovation... 'Harmful interference' is interpreted relative to past performance, and since performance is constantly changing, any technical definition would have to change constantly, as well". . . and "Nortel urges that the Commission maintain consistency with international definitions." [35]

[34] Comment of Comsearch at 7-8.

[35] Comments of Nortel Networks at 1. ***See also***, for example, the Comments **of** Wayne Longman at **15**-16, who contends that a quantified definition would "cause more disputes than it resolves"; Comments of NASA at **7,** which state that "considering new definitions could be detrimental to commercial as well **as** Federal agencies that rely on such technical criteria for design and development of new radio systems;" and the Comments **of** Telesat Canada at **3.**

Several commenters point out that the generic definition of "harmful interference" allows the Commission to interpret its meaning differently for particular radio services. According to Verizon Wireless, "lt is not the definition of 'harmful interference' that is in need of change but the way in which the Commission enforces its rules or establishes policies regarding interference."[36]

Other commenters urge the Commission to clarify or change the current definition of ***harmful interference.*** Sprint contends the current definition has several weaknesses: it is highly subjective - the terms "serious degradation" and "repeated interruptions" are not defined and are open to ad ***hoc*** interpretation; it does not sufficiently address the current RF environment and modem technology (i.e., adaptive capabilities of modem communications systems); and that the definition is too general." According to Sprint, "The specific definition of 'harmful interference' should depend on the nature of the victim service and the function it is intended to serve."[38] Xtreme Spectrum contends that the current definition of ***harmful interference*** causes uncertainty and suggests that the definition's subjective nature accounted for much of the controversy in the ultra, wideband proceeding.[39] **As** a better approach, it recommends a system of interference protection based on quantitative measures of harmful interference (degradation or interruption) a given service can tolerate.

The Satellite Industry Association ("SIA") comments that harmful interference is an extreme level and that just because interference does not rise to this level, it cannot be concluded that the interference is acceptable to the victim.[40] According to **SIA,** attempts to quantify the level of harmful interference would not be useful. Rather, efforts should he made to ensure that levels of interference will not result in service interruption or degradation, a level characterized as "acceptable" interference – the level operators would coordinate among themselves. **SIA** suggests that, when adopting spectrum sharing criteria, the Commission use the terms "permissible or acceptable" interference.[41]

Steve Baruch expressed a somewhat similar view at the Commission's Interference Protection Workshop. He indicated that a level of interference could be harmful or not harmful depending on the victim and that attempts to quantify ***harmful interference*** amount to identifying acceptable or tolerable levels of interference to parties sharing the spectrum. According to Mr. Baruch, "You can identify objective limits of what would be tolerable, hut not would be harmful."

[36] Comments of Verizon Wireless at 7. *See* ***also*** Comments of the Satellite Industry Association **at** 10; and Comments of Cingular Wireless LLC at **40.**
[37] Comments of Sprint at 13-17. *See also* Comments of National Public Radio at 14.
[38] *Id.* at 15.
[39] Comments of Xtreme Spectrum, Inc. at 6-9. According to Xtreme Spectrum, "In the ultra-wide band proceeding the parties generally concurred on the appropriate techniques for predicting interference, but differed greatly on what assumptions to use – and consequently differed on whether interference would or would not occur in practice." *Id.* at **8.**
[40] Comments of the Satellite **Industry** Association at 10-11.
[41] *Id.*

Need for more explicit interference protections: s r ed, some parties recommend that more explicit protections be built into the definitions of interference. Others urge the Commission to give careful consideration to the condition of the RF noise floor.[42] According to Cingular Wireless:

> ...increasing the noise tlour b: even a few dB may adversely impact existing licensed systems and their customers in a number of ways, such as: (1) coverage, (2) syst p it (3) li ibilit of data throughput, and (4) quality of voice service. To overcome these effects, licensees may have to reconfigure previously optimized systems and deploy additional facilities to reg i what the noise floor increase erased. Thus, the incumbent's service should be considered 'seriously degraded, obstructed, or repeatedly interrupted,' constituting harmful interference, as a result of the newly authorized spectrum assignment.'[43]

Cingular Wireless also notes that the Commission could set signal strength limits that would "establish a rebuttable presumption against interference or noninterference with respect tc particular technologies and services, g into account industry standards, prevailing noise levels, receiver characteristics and other factors."[44]

At the Interference Protection Workshop David Hageman urged a common approach for measuring interference compliance:

> "I thi that if you're going to do something that way, you d to have clearly d it You need t come up with some way that th com on person out there small carrier, can take a pectrum analyzer or some common piece of equipment itl some standard things that they have and say I'll stick this antenna up and I'll make this measurement and I'll turn thi knob d set that switch and, bang, here's my level. i l it meets it or it doesn't. And it needs to be the same for every one "[45]

Several commenters recommend that the Commission pay attention to the cumulative or aggregate effects of interference f multiple RF emitters.[46] For example, according t th Association for Maximum Service Television and the National Association of Broadcasters:

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[42] *See*, for example, Comments of Cingular Wireless LLC at **41;** Comments of Dominion Resources, Inc. at 5-6; Comments of **NASA** at 7; and AT&T Wireless Service at 15.
[43] Comments of Cingular Wireless LLC at 41.
[44] *Id.* **at** 43. ***See also*** the Comments **of** Motorola, Inc. at 17 ("The level of interference that can be tolerated may vary depending on the nature of the service involved."); and the Comments of Dr. Charles L. Jackson at 2 ("If licenses contained clauses stating that licensees would have to accept **up** to some specific level of co-channel and adjacent channel energy, then some such disputes would be easier to resolve, or might not be disputes at all.")
[45] In this context, **Mr.** Hageman reflected on **a** past experience in which he was informed that there are multiple formulas for calculating a field strength limit at a service area boundary.
[46] Comments of Telesat Canada at **2;** Comments of Bell South at **7.**

"The Commission typically conducts an ***ad hoc,*** case-by-case interference analysis and considers the harmful interference caused on an incremental basis Thus, even if each new spectrum use does not cause significant interference to existing spectrum users, the *cumulative* effect of all the new spectrum uses authorized in recent years has degraded the quality of the spectrum for all users."[47]

As another means of more explicit protection, a commenter suggests that as spectrum demand increases, incumbent users he required or provided incentives to migrate to the use of more robust and spectrally efficient technologies, accompanied by required use interference avoidance and mitigation techniques!'

Finally, some commenters discuss the need for more explicit protection in terms of "interference rights"; contending, for example, that incumbent users should not be subjected to additional unwanted interference.[49]

C. Conclusions

1. There is a need to quantify acceptable levels of actual interference:

The previous section highlighted future challenges to the effectiveness of the current interference management paradigms, as the Commission seeks to accommodate the high demand for spectrum-based services and devices for both licensed and unlicensed services. Approaches such as predictive modeling, laboratory compatibility testing of signal waveforms and spectrum use decisions based on knowledge of the local environment – standing alone – will he increasingly strained by the increasing intensity of spectrum use and the changing nature of the RF environment, especially in urban areas of the country. The radio environment will be increasingly characterized by flexible service offerings with a multitude of signal waveforms and by higher densities of low power RF emitters with small signal ranges. The cumulative effects of these devices and other sources of RF energy will raise the noise floor and could threaten the reliability of existing communication services.

As a result of these factors, it will not always he possible to guarantee well-defined interference protection rights based on comprehensive predictive analyses. Nor will current interference management approaches inform the Commission of the intensity of spectrum use or the condition of the RF noise floor as it considers spectrum for new technologies or to accommodate the growth of existng services.[50]

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[47] Comments of MSTV/NAB at 12-13.
[48] Comments of Carl Stevenson.
[49] *See,* for example, the Comments of AT&T Wireless Service at 14; Comments of **SIA at** 13-14; and the Comments **of** Wayne Longman at 16.
[50] Since most **of** the favored spectrum bands are already in use, much of the future demand may be in the form **of** requests to share spectrum with incumbent licensees, **for** example, by placing **very** low power **RF** devices "underneath" the much higher emission **levels of** incumbent **users.**

The Working Group concludes that the current definitions of interference in Part *2* of the Commission's Rules adequately address the broad and changing technical and operational characteristics of the many radio services.[51] Rather than change the definitions, the Working Group recommends that the Commission consider addressing its long-term interference management and spectrum policy challenges by supplementing its transmitter-centric approach with a new paradigm based on (1) real-time measurements of spectrum use and the RF environment and **(2)** adaptive responses of transmitters and receivers to these measurements. **As** set forth below, maximum acceptable levels of interference could be established to provide well-defined protection rights to incumbents. Such threshold levels could also be used as a basis for permitting additional spectrum access to new RF-based technologies and services.

Commenters and workshop participants indicate that technology for sensing and reacting to the interference environment is now available.[52] For example, according to Sprint, "the **IS-95** code-division multiple access ("CDMA") air interface used in PCS and cellular networks uses transmit power control on both uplink and downlink transmissions.. .If the interference at the receiver is increased, the transmitter will increase **its** power output to compensate – up to a limit." Personal Telecom Tech, Inc. comments that "Frequency-agile technology via softwaredefined radio technology can be used to monitor power in spectrum bands and thus determine where channels might not be used or not available for licensed services due to buildout and deployment or environmental or topological considerations." The nest section of the Working Group report discusses how interference measurements could be combined with adaptive transmitter control technology to limit interference to within established levels.

2. <u>**As** a long-term strategy, the Commission should consider **use** of the "Interference Temperature" metric as a means of quantifying and managing interference</u>:

As introduced in this report, "interference temperature" is a measure of the RF power available at a receiving antenna to be delivered to a receiver – power generated by other emitters and noise sources.[53] More specifically, it is the temperature equivalent of the RF power available at a receiving antenna per unit bandwidth, measured in units of

[51] The definitions in Section 2.1(c) of the Commission's Rules are sufficient for their intended purpose, provided they clearly state that means of interference protection may be tailored to specific services. We agree with commenters that any efforts to effect significant changes to these definitions should be well coordinated with all affected stake holders. The Commission may wish to consider a larger role domestically for the definitions of "permissible" and "acceptable" interference, in the manner in which these are used in the Satellite services.

[52] Comments of Personal Telecom Tech, Inc. at 2. Further, Jack Rosa of HYPRES, Inc. stated the following at the Interference Protection Workshop: "If you had a fast enough machine you could monitor the spectrum continuously. You could put in intelligent controllers, so-called bandwidth on demand. That technology can be accomplished now." A variety of devices are now commonly used to measure RF energy. The key is to integrate these devices with high speed frequency monitoring technology.

[53] The related term "noise temperature" is used by radio astronomers as a measure of the intensity of radiations from space. The noise temperature concept is also used in the satellite industry in connection with determinations of the need for international frequency coordination.

°Kelvin.[54] **As** conceptualized by the Working Group, the terms "interference temperature" and "antenna temperature" are synonymous.[55] The term "interference temperature" is more descriptive for interference management, [56]

Use of the interference temperature concept would be more amenable to an RF environment having the properties of additive Gaussian white noise; *i.e.*, with signals having uniform power spectral density over their frequency bandwidth. For such signals, the received power at the output terminals of the antenna could be calculated as the product of the interference temperature, the bandwidth and Boltzman's Consent."

As illustrated in Figure 1, interference temperature measurements could be taken at receiver locations throughout the service areas of protected comniunications systems, thus estimating the real-time conditions of the RF environment.

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[54] Interference temperature can be calculated **as** the power received by anantenna (watts) divided by the associated RF bandwidth (hertz) and **a** term **known** as Boltzman's Constant (equal to 1.3807 watt-sec/°Kelvin). Alternatively, it can be calculated **as** the power flux density available at **a** receiving antenna (watts per meter squared), multiplied by the effective capture area of the antenna (meter squared), with this quantity divided by the associated RF bandwidth (hertz) and Boltzman's Constant. An "interference temperature density" could also be defined as the interference temperature per unit area, expressed in units of 'Kelvin per meter squared and calculated as the interference temperature divided by the effective capture area of the receiving antenna -- determined by the antenna gain and the received frequency. Interference temperature density could be measured for particular frequencies using a reference antenna with known gain. Thereafter, it could be treated as a signal propagation variable independent of receiving antenna characteristics.

[55] The idea of an interference remperature as a **measure** of the antenna "noise" power in a particular band and location is well established. ***See,*** for example, Wolfram Research at http://scienceworld.wolfram.com/physics/AntennaTemperature.html.

[56] Interference temperature is a component of the total noise temperature of **a** receiving system, which also includes the thermal noise generated within the receiver. The publication, "Telecommunications: Glossary of Telecommunications Terms," prepared by the National Communications System's Technology & Standards Division and Published by the General Services Administration defines "noise temperature" as fallows: "At a pair of terminals, the temperature of a **passive** system having an available noise power per unit bandwidth at a specified frequency equal to that of the actual terminals of a network (the underlined terms are, in turn, **also** defined; for example, noise power is the "Interfering and unwanted power in an electrical device or system"). ***See*** http://www.its.bldrdoc.gov/fs-1037/dir-024/_3565.htm.

[57] The spectral characteristics of non-Gaussian signals generally are not scalable; *e.g.*, the total power in a frequency bandwidth cannot readily be extrapolated from the power level for a sub interval of that bandwidth. Thus, if an interference temperature "thermometer" measured the temperature of a portion of the bandwidth of such a communications system, that value could not be assumed to be constant over the entire bandwidth. The thermometer would need to measure frequency intervals comprising the whale bandwidth and use the largest measured temperature value to characterize the environmentfor the particular receiver.

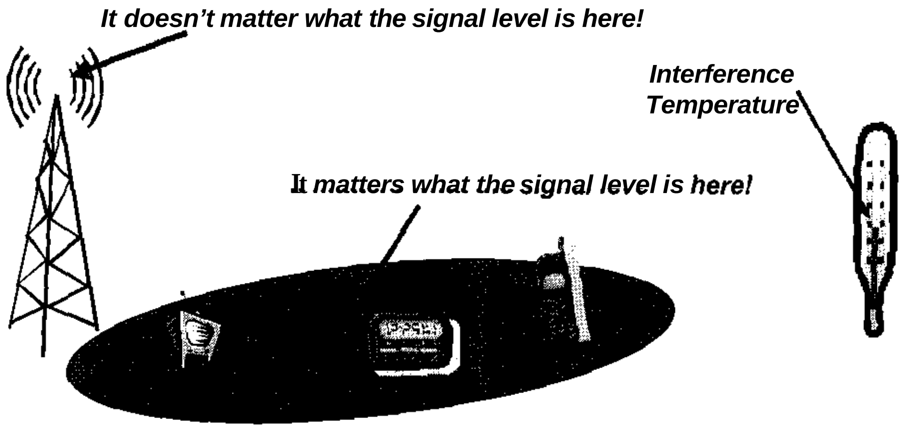

Figure 1

Like other representations of radio signals, instantaneous values of interference temperature would vary with time and, thus, would need to be treated statistically. The Working Group envisions that interference "thermometers" could continuously monitor particular frequency bands, measure and record interference temperature values and compute appropriate aggregate value(s). These real-time values could govern the operation of nearby RF emitters. Measurement devices could be designed with the option to include or exclude the on-channel energy contributions of particular signals with known characteristics; *e.g.,* the emissions of users in geographic areas and bands where spectrum is assigned to licensees for exclusive use.[58]

The Commission could use the interference temperature metric to set maximum acceptable levels of interference, thus establishing a "worst case" environment in which a receiver would operate. Interference temperature thresholds could thus be used, where appropriate, to define interference protection rights. Several commenters support capping interference levels?' Threshold levels could he set for different hands, geographic regions or services after the Commission has reviewed the condition of the RF

[58] It may be technically complex to estimate the interference temperature excluding the licensed desired users. A simple measurement in this case would overestimate the actual interference temperature, but may be adequate in many cases because it would err on the side of preventing unwanted interference.

[59] ***See,*** for example, the Comments of Sky Tower; Comments of CTIA at 12 (suggesting a "zoning-like" model for determining what is acceptable interference); Comments of Sprint at 17 (suggesting **a** "harmful interference" threshold to cap the "total interference effect from **all** overlaid or coexisting systems. Once the interference effect reaches the cap, **no** more secondary devices or systems would be authorized to share the affected band.").

environment.[60] These levels could serve as benchmarks to guide engineering tradeoffs for radio equipment and system designers!'

D. Recommendations

- The Working Group recommends that, as a long-term strategy, the Commission consider the interference temperature metric for quantifying and managing interference, together with established "acceptable" levels of interference.

- The Working Group recommends that the Commission promote and hasten the transition from analog to digital transmission techniques and, if necessary, effect this transition by rule. Digital operations are generally more resistant to interference and would enhance **use** of the interference temperature metric.

V. Transmitter Enhancement for Interference Control

A. Current regulations

The Commission's Rules prescribe upper limits for in-band transmitter power and out-of-band emissions for the majority of spectrum uses. Automatic transmitter power control ("ATPC") to ensure transmission of the minimum power necessary for reliable communications is generally not required. The rules do provide that all satellite earth stations in the 20130 GHz band "shall employ uplink adaptive power control or other methods of fade compensation such that the earth station transmissions shall be conducted at the power level required to meet the desired link performance while reducing the level of mutual interference between networks.'[62] Earth stations in the Fixed Satellite Service operating in the 13.77 to 13.78 GHz band may use ATPC to increase power to compensate for rain attenuation.[63] Additionally, the Commission recently adopted rules to permit licensees in the radio and television broadcast auxiliary and cable relay services to use ATPC.[64]

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[60] In considering candidate bands for interference temperature thresholds, the Commission should take into account such other factors as the nature and extent of incumbency and the nature of the spectrum use. For example, it may not be appropriate to use the concept **for** certain public safety services.

[61] Acceptable "interference temperature" limits could, in effect, provide implicit receiver standards, because equipment manufacturers would have the option *of* designing receivers to operate in "worst case" RF environments.

[62] 47 C.F.R. § 25.204 (g). In ATPC systems, when a receiver detects a decrease in the necessary signal strength, it sends **a** control signal to the transmitter to increase power

[63] 41 C.F.R. § 25.204 (f).

[64] *See* Revisions to Broadcast Auxiliary Service Rules in Part 74 and Conforming Technical Rules for Broadcast Auxiliary Service, Cable Television Relay Service and Fixed Services in Parts 74, 78 and 101 of the Commission's Rules, FCC 02-298, *Report and Order* in ET Docket No. 01-75, adopted October 30, 2002.

B. Views expressed in the public record

The record in this proceeding indicates that ATPC and other adaptive technologies are now in use. At the Interference Protection Workshop, Dr. Andrew Clegg stated that his company, Cingular Wireless, has "already deployed power control as tightly as we can..." Sprint comments that its CDMA PCS and cellular systems use transmitter power control for uplink and downlink transmissions.[65] **As** an alternative to power control, it comments that wireless local area network standards IEEE 802.11(a) and (b) provide for data rate adaptation, whereby reductions in the signal to interference ratio due to interference can be compensated by a reduction in the transmitted data rate.[66]

Commenters and workshop participants report that advances in cognitive radios, antennas and signal processing and coding areevolving and may soon become practical and without the high costs usually associated with implementing new technologies.[67] According to Vanu, Inc., a soft-ware defined radio ("SDR) proponent:

> "SDR will permit devices to alter the signal processing they are performing in order to get the best performance for the current conditions. For example, under poor signal to noise conditions, aggressive forward error correction may he called for. As conditions improve, the error correction could be modified in ader to get improved data rates. Without the flexibility to make these changes quickly and inexpensively, the benefits of adaptation for the current operating environment could not be realized ....SDR will at times be helpful in addressing harmful interference issues as quickly and efficiently as possible'"

Dr. David Reed offers further perspective on emerging technology:

> "[W]e must recognize that in the not-too-distant future, all radio systems will he based on digital signal processing, and thus will approach 'Cognitive Radio' capability. By cooperatively sensing and manipulating their electromagnetic environment, a network of software defined radio transceivers can adapt to their physical environment to match demand much closer to the capacity achievable by joint action of a group of radios."[69]

HYPRES, Inc., another SDR proponent, describes an automated system to dynamically monitor broad areas of spectrum and to "pass details of observed signal characteristics to central controllers for evaluation."[70] HYPRES suggests that the Commission consider implementing a monitoring capability to provide data for spectrum management. It notes that among the techniques made possible by the related technology

[65] Comments of Sprint at 14

[66] *Id.* at IS.

[67] According to remarks made by Jack Rosa of HYPRES, Inc. at the Interference Protection Workshop, indications are that the next generation of technology will cost "dramatically less" than current systems based on current technology.

[68] Comments of Vanu, Inc. at 4-5.

[69] Comments of David Reed at 8-9.

[70] Comments of **HYPRES,** Inc. at 2-3.

is the "spotting [of] interfering emitters to support adaptive cancellation and/or null steering of adaptive antennas."[71]

C. Conclusions

The Working Group believes that signal sensing and adaptive technology, such as that now used for ATPC, will become increasing sophisticated and could play a major role in the self-regulation of interference. Such technology could be used in conjunction with the interference temperature metric to ensure that the condition of the RF environment does not exceed permissible levels.

1. The Commission should make clear that its spectrum policies are based on "interferencelimited" rather than "ambient noise limited" environments.[72]

An interferencelimited policy reflects typical RF environments, enhances frequency reuse, and would facilitate use of the interference temperature metric and established acceptable interference limits.

2. The Commission should consider extended use of environmental sensing and control technology, including technology that could be used in coniunction with the interference temperature metric.

The comments of Dr. David Reed in this regard are insightful:

> "As long as the regulatory process (including litigation and lobbing, and even secondary markets) focuses on defining interference without reference to the actual dynamics of systems, there will be no means in the reduction of 'actual' interference (as opposed to the current measure of 'imaginary' interference)."[73]

The Working Group describes an approach in which transmitters and receivers using advancing technologies could interactwith the RF environment. In addition to the interference temperature metric, there are three major elements: (1) the information an emitter would need to adapt to the environment to ensure that a maximum acceptable interference threshold is not exceeded, (2) the manner of acquiring interference temperature data and delivering this data to the emitter, and (3) the responses of the emitter to the data.

An RF emitter would need to know the interference temperature (or, alternatively, the interference temperature density) at locations within its nominal signal range. This data could be acquired in several ways. It could be measured directly by the emitter; *e.g.,* for low power devices with very small signal ranges. More generally, a grid of spectrum

[71] *IJ.* at 3.
[72] In a noise-limited environment, the range of a signal is determined in the assumed absence of interfering signals. In an interferencelimited environment, the range is determined in the presence of interfering signals.
[73] Comments of David Reed at 16–19.

monitoring stations could be established that would continuously scan the RF environment for particular frequency bands, process the data and broadcast packetized interference temperature data from omni-directional antennas transmitting on dedicated frequencies. Data packets could also include the geographic location of the interference temperature measurement, the associated frequency or frequency band and the measurement bandwidth. **As** another means of data delivery, transmitters and receivers operating in the environment – for example, in "an adaptive ***ad hoc*** wireless network" – could be equipped with interference temperature "thermometers" and GPS sensors to determine measurement locations. The devices in the network would constantly measure interference temperature and route real-time data packets through the network. RF devices not in the network could also be equipped to measure and send this information.

For devices required to conform to interference temperature thresholds, responses could include a reduction in transmitter power, antenna beam reshaping, selection of a different transmitting frequency or a "stand down" decision to wait until the environment adjusted to permit a transmission that would not cause an acceptable interference levelto be exceeded within the emitter's nominal signal range. The sensoryicontrol system could thus provide a self-enforcing mechanism to ensure the integrity of the interference temperature limit for that frequency band, service and geographic area. **As** anadditional benefit, such an approach could provide data to update a Commission data base on the condition of the RF noise floor.

Potentially significant benefits of using the interference temperature metric with sensory/control devices are illustrated in Figures 2 and **3.**

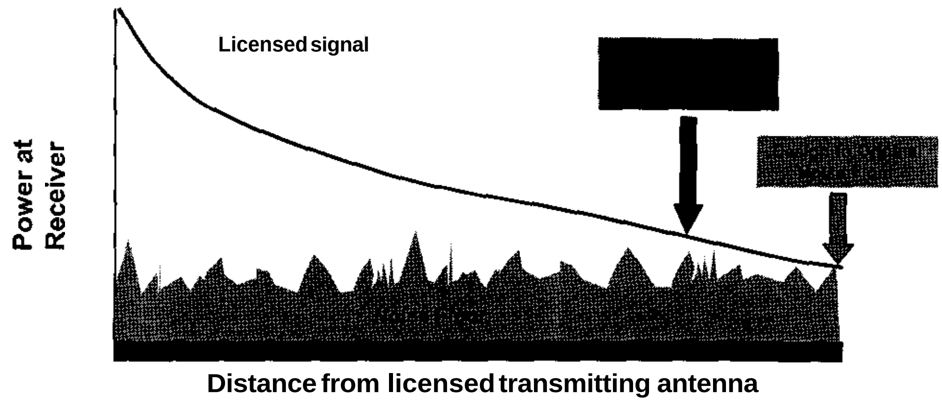

Figure 2

Figure 2 depicts a communications system designed to operate within a signal range at which the received power level approaches the noise floor that existed when the system was established. **As** additional interfering signals are added – for example, due to further aggregation of unlicensed devices or out of hand emissions from new users – the noise floor can rise unpredictably. **As** a result, service reliability and signal coverage could he increasingly worsened without warning to the system licensee.

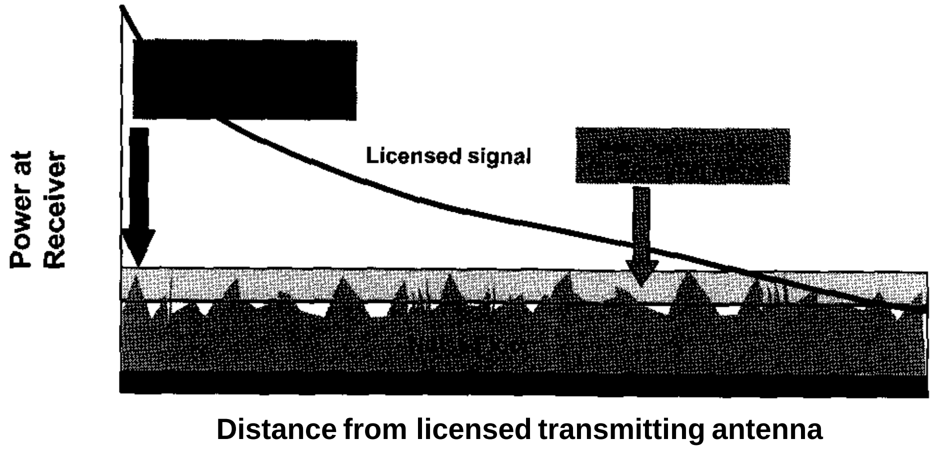

Figure 3

In Figure 3, the evisceration of service **is** capped by an "acceptable" interference temperature. In those portions of the signal path for which the temperature limit has not been exceeded, opportunities would exist for additional spectrum **use;** *e.g.*, by low power "underlay" emitters equipped with interference temperature "thermometers" and transmission "controlling" devices. In the longterm, this approach could also possibly be used **as** an alternate means of regulating out-of-band transmitter emissions; *i.e.*, in lieu of more expensive transmitter filtering.

3. <u>Interference management could be enhanced to the extent the strengths of emitter-generated signals are spatially uniform over nominal signal ranges.</u>

The Working Group believes that signal strength uniformity could enhance interference management and, in particular, the accuracy of the environmental sensory/control approach; for example, by avoiding complications caused by RF "hot spots." Antenna technology now exists to facilitate signal strength uniformity. Use of low power distributed transmission networks, in combination with beam shaping antennas, could also serve this purpose.

4. <u>Effective interference mitigation could also be advanced through **use** of modern transmitter output filtering and related digital signal processing capabilities.</u>

Use of such technologies could increase the "purity" of transmitted signals and reduce interference caused by adjacent channel "splatter". In this regard, the Working Group concludes that it would be appropriate for the Commission to consider the gradual tightening of out-of-band emission limits in its rules for the various radio services.

D. Recommendations

- The Working recommends that the Commission affirm that its interference management policies will be generally based on interferencelimited RF environments.

- The Working Group recommends that the Commission promote transmitter enhancements **as** a means of interference management; for example, increased use of automatic transmitter power control.

- As a long-term strategy, the Working Group recommends that Commission consider augmenting existing interference management approaches by promoting the use of self-enforcing environmental sensing and adaptive transmitter control technology, in conjunction with use of the interference temperature metric.

- The Working Group recommends that the Commission promote the use of technologies that enhance the spatial uniformity of signal levels.

- The Working Group recommends that the Commission begin to examine the out-of-band emission limits in its rules in light of modem technology and related costs, with a view toward gradually tightening existing limits.

VI. Allocating Spectrum to Radiocommunications Services that are Grouped Together by Their Similar Technical Characteristics

The Commission's mission **is** 'to promote the public interest through a fully competitive marketplace -- with access for all Americans to communications services -- in a cost-effective, efficient, and transparent regulatory environment." To realize this mission, spectrum managers should allocate spectrum to radiocommunication services within the same frequency band or to services in adjacent frequency bands in a way that places the fewest technical and regulatory constraints on **all** of the services in that spectrum. With fewer constraints, licensees will have the flexibility to deploy equipment in a cost-effective manner that has the greatest promise of consumer acceptance of new and innovative communication services. The Commission can foster spectrum efficiency and flexibility by allocating spectrum to radiocommunication services that are grouped together by their similar technical characteristics.

A. International Telecommunication Union (ITU) and FCC Spectrum Allocation Processes

Implementation of a new radiocommunications system requires substantial lead time for design and implementation particularly if the system requires a new service allocation and interference protection. Protection from interfering sources, both in-band and adjacent band, requires that service allocations are made whereby the systems operating in the spectrum are technically compatible. Technical compatibility among the radiocommunication systems leads to more efficient use of the spectrum and less constraints on the systems operating within a particular service allocation. This portion of the report summarizes the current international and domestic service allocation processes, finds that the Commission does already promote the "zoning" approach to spectrum allocations internationally, and concludes that a similar approach should he considered domestically in order to promote its goals of placing the fewest operating constraints on new systems without disrupting the operating environment that currently operating radiocommunication systems rely on.

1. International approach to spectrum allocations

International spectrum allocations are made to radiocommunication services such as Broadcasting or Fixed-Satellite, not to systems. Service allocations are broad in scope. The Commission participates in the ITU spectrum allocation process with other U.S. Government agencies, the U.S. industry, and foreign administrations. The Commission considers industry proposals and positions that focus on future spectrum uses and it tries to reconcile the many competing interests associated with a new spectrum allocation keeping in mind the practicality of the operating constraints on the systems operating in the allocations.

Article 5 of the International Radio Regulations contains the International Table ***of*** Frequency Allocations. This table has been developed over the past century[74] under the auspices of the ITU. Over the years a multistep technical approach has evolved to determine which radiocommunication services are able to share spectrum with other services. Generally, the steps are as follows:

i) Technical description of service **A** detailed description of the technical parameters of the new service are developed and introduced into the appropriate ITU technical study group. These parameters include, but are not limited to, items such as the expected transmit power, antenna gain, geographic service area, receiver sensitivity, types of modulation employed and the types of applications proposed. This information is necessary to introduce the technical concepts of the new service to other members of the study group.

ii) Selecting applicable frequency range. Some wireless systems can only he implemented at a specific frequency or range **of** frequencies.[75] Other systems, due to atmospheric propagation affects and/or the current state of technology, can **be** implemented over a fairly wide frequency range such as **1-3** GHz. Generally, two frequency ranges are considered. One in which the system **is** capable of being implemented and, two, a preferred frequency range within which the future system operators would realize fewer constraints on system implementation.

iii) Spectrum sharing studies. Much of the frequency spectrum that ***is*** technically suitable for the implementation of a new communication system **is** already occupied by

[74] As an example of the progress in radio technology, the Final Acts **of** the 1949 ITU Radio Conference contain, in Article ***5***, a Table of Frequency Allocations from 10 kHz to 10.5 MHz. The current Article ***5*** extends from 9 kHz to **275** GHz.

[75] Some types of earth-resource and radio astronomy sensing detect the emissions of atoms or molecules that only occur at specific frequencies. Other **types** of sensing, such as **sea** surface wave height are best accomplished over fairly narrow bands of frequencies.